ELSEVIER

The Journal of Emergency Medicine, Vol. 46, No. 2, pp. 241–249, 2014

0736-4679/$ - see front matter

http://dx.doi.org/10.1016/j.jemermed.2013.05.026

Administration of Emergency Medicine

EMERGENCY DEPARTMENT OCCUPANCY RATIO IS ASSOCIATED WITH INCREASED EARLY MORTALITY

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☐ **Abstract—Background: To measure emergency department (ED) crowding, the emergency department occupancy ratio (EDOR) was introduced. Objective: Our aim was to determine whether the EDOR is associated with mortality in adult patients who visited the study hospital ED. Methods: We reviewed data on all patients who visited the ED of an urban tertiary academic hospital in Korea for 2 consecutive years. The EDOR is defined by the total number of patients in the ED divided by the number of licensed ED beds. We tested the association between the EDOR (quartile) and each outcome using a multivariable logistic regression analysis adjusted for potential confounders: age, sex, emergency medical services transport, transferred case, weekend visit, shift, triage acuity, visit cause of injury, operation, vital signs, intensive care unit or ward admission, and ED length of stay (quartile). The main outcome measures were survival status at discharge and at 1–7 days. Results: A total of 54,410 adult patients were enrolled. The EDOR ranged from 0.41 to 2.31 and the median was 1.24. On multivariable analyses, in comparison with the lowest (first) quartile, the highest (fourth) quartile of the EDOR was associated with 1-day mortality (adjusted odds ratio [OR] = 1.42; 95% confidence interval [CI] 1.08–1.88), 2-day mortality (adjusted OR = 1.31; 95% CI 1.04–1.67), and 3-day mortality (adjusted OR = 1.27; 95% CI 1.02–1.58). The EDOR was not significantly associated with 4- to 7-day mortalities and overall mortality at discharge. Conclusions: The EDOR is associated with increased 1- to 3-day mortality even after controlling for potential confounders. © 2014 Elsevier Inc.**

☐ **Keywords—emergency department; crowding; poor outcome; emergency department occupancy ratio**

INTRODUCTION

Emergency department (ED) crowding has been a major problem of health care systems worldwide (1). During the past decades, the input-throughput-output model was the most widely accepted conceptual framework for ED crowding and many crowding measures regarding each step of this model have been introduced (2).

In 2008, McCarthy et al. proposed the emergency department occupancy rate (referred to here as the emergency department occupancy ratio [EDOR]) as a simple measurement of ED crowding (3). The EDOR is the ratio of the total number of patients in the ED to the total number of ED treatment bays. Because of its simplicity, the EDOR is easy to calculate and can be used in real-time situations. Researchers have demonstrated that the EDOR is significantly associated with a clinician's opinion of crowding, discrimination of diversion and left without being seen (LWBS), and poor treatment quality (3–8).

Despite agreement on the extent and adverse effects of ED crowding, there is no standard measurement for ED

Received: 18 August 2012; Final submission received: 10 January 2013;
Accepted: 1 May 2013

crowding among many ED crowding measurement tools (9,10). This implies that there is no single measure to meet the criteria, until now, that is easy to use or calculate, easy to trace in real time and therefore possible to use for early warning and planning, and validated as being associated with poor quality of care. The EDOR seems to meet all these criteria. However, until now, there has been no report showing the relationship between the EDOR and increased mortality in a large cohort. This study is important in the development of a consensus for standard measurement for ED crowding.

The present study aimed to determine whether the EDOR is associated with an increase in overall mortality in adult patients who visited the ED of the study hospital, even after adjusting for potential confounders. Because the effect on mortality of ED crowding is likely to be greatest early in a hospital stay and diminish over time, we determined outcomes that included 1- to 7-day mortality in addition to overall mortality. In the present study, the overall mortality includes in-hospital mortality and in-ED mortality. The EDOR was calculated using the visit data of adult and pediatric patients to the ED because the study hospital ED did not separate a treatment area for pediatric patients during the study period. However, considering the difficulty of age adjustment in pediatric patients, we analyzed the data of adult patients only.

METHODS

Study Design

We performed a retrospective analysis of all consecutive adult patients who registered in our ED between January 1, 2009 and December 31, 2010. This study was approved by the Institutional Review Board of the study hospital and a waiver for informed consent was obtained.

Setting and Selection of Participants

The study was conducted at a 1000-bed urban academic tertiary-care hospital. The study hospital has an electronic order communication system (OCS) in place. OCS is an integrated health information system that manages patient registration, medical data collection, and prescription management for patient care activities. The study hospital is a regional percutaneous coronary intervention (PCI) facility and is available for 24-hour interventions. The study hospital also serves as a regional trauma center. The study hospital offers medical, surgical, coronary, neurological, and pediatric intensive care unit (ICU) services. There are about 35,000 ED visits per year at the study hospital. All adult patients aged 15 years or older who visited the ED were considered eligible for the study.

In the hospital, all ED visitors must register in the OCS before they go to triage. At triage, all patients are checked for vital signs including systolic blood pressure, diastolic blood pressure, pulse rate, respiratory rate, body temperature, peripheral oxygen saturation, and central nervous system (CNS) status. CNS status is recorded using a scale of alert, verbal, painful, unresponsive (AVPU) in the study hospital ED. A triage nurse assesses acuity using a 5-point scale including immediate, emergency, urgent, semi-urgent, and non-urgent. A triage nurse enters this information into the OCS and prints the chart. After triage, a complete history is taken and a full physical examination is performed by the attending physician in the ED. Laboratory tests and radiologic evaluations are conducted as necessary. Medical records are computerized after patients are discharged.

There are three shifts in the study hospital, 7 am to 3 pm (day), 3 pm to 11 pm (evening), and 11 pm to 7 am (night). The same number of emergency doctors (n = 5) and emergency medical technicians (n = 2) worked in each shift. There are 9 nurses during the day, 10 during the evening, and 8 during the night shifts.

Methods of Measurement

The EDOR is defined as the total number of patients in the ED divided by the number of licensed ED beds. The numerator includes all patients in the ED at any point regardless of any throughput process after registration (i.e., triage, examination by doctors, diagnostic evaluation, treatment, and boarding). The denominator includes the total number of licensed treatment bays as defined by the ED's original blueprint, but excludes hallway locations. There were 42 licensed ED beds during the entire study period. There was no remodeling of ED areas during the study period.

The EDOR is calculated using collected OCS data when patients registered in the OCS. When patient "A" visited the hospital and registered in the ED, for example, if 41 patients are already in the ED before "A" visits, EDO becomes 42 (41 [previously existing patients] + 1 [new patient, "A"]) and EDOR becomes 1 (42 [total patients in the ED]/42 [licensed beds in the ED]).

Because the effect on mortality of ED crowding is likely to be greatest early in a hospital stay and diminish over time, we set the main outcomes of the survival status at days 1–7 regardless of patients' position at hospital, ED, or home. To determine survival status of patients who were not in the hospital each day, we investigated follow-up date of all enrolled patients using OCS. For patients for whom follow-up data were not available for day by day survival status, we treated their survival status as missing data. We also set overall hospital mortality as the main outcome. Because a negative effect of ED

crowding can manifest both during ED stay and after the hospital admission as a mortality case, overall hospital mortality includes in-hospital mortality and in-ED mortality in the present study. Dead on arrival (DOA) cases were not regarded as mortality cases.

Data Collection and Processing

Between January 1, 2009 and December 31, 2010, the following data elements were extracted from the OCS for each registered patient: age, sex, date and time of ED arrival, date and time of ED discharge, date and time of hospital admission, date and time of hospital discharge, visit cause (injury or noninjury), surgical intervention at the time of presentation to the ED, survival status on discharge, and admission to the intensive care unit or to a general ward. Systolic and diastolic blood pressure, pulse rate, respiratory rate, body temperature, and AVPU status on arrival at the ED were obtained.

In the study hospital, when the patient chart is printed out at the beginning of the ED course, administrative variables from the OCS are already put in the chart. For that reason, data on the OCS and data on a paper chart are absolutely equal. Therefore, a chart review for data validation was not performed.

The EDOR was calculated using a dataset and assigned to each patient. Because the study hospital ED did not separate a treatment area for pediatric patients during the study period, we included data for pediatric patients and the EDOR was calculated for all patients.

Primary Data Analysis

All continuous data are presented as mean (standard deviation) in cases with normal distributions. All discrete data are presented as both numbers and percentages. Logistic regression analyses results are presented as odds ratio with a 95% confidence interval. Statistical significance was defined as Wald χ^2 test $p < 0.05$.

Logistic regression analyses were conducted to adjust for the effects of the EDOR (as a categorical variable using quartile) on each outcome, and for possible confounding factors. The model considered age, sex, emergency medical services (EMS) transport, transferred case, day of week (weekend and holiday vs. nonweekend), shift (day, evening, and night), triage acuity (immediate, emergent, urgent, semi-urgent, and nonurgent), visit cause (injury cause vs. noninjury cause), operation, mean arterial pressure, pulse rate, respiratory rate, body temperature, mental status (AVPU scale), whether to admit (ED discharge, ward admission, or ICU admission), and ED length of stay (as a categorical variable using quartile).

All analyses were conducted using STATA 11.1 (StataCorp LP, College Station, TX) and SAS 9.1 (SAS Institute Inc., Cary, NC) software.

RESULTS

Characteristics of Study Subjects

There were 68,067 ED visits during the study period. Mean EDOR was 1.25 ± 0.26. Median EDOR was 1.24 (interquartile range [IQR] 1.07–1.42) and ranged from 0.41 to 2.31 showing unimodal and symmetrical distribution (Figure 1). We excluded 13,657 patients who were younger than age 15 years, leaving 54,410 subjects in the study period. Mean subject age was 53.9 ± 19.3 years, with men comprising a larger proportion of the study cohort (55.6%). In the study, 16,986 (31.2%) subjects were admitted to the general wards and 3441 (6.3%) were admitted to ICUs. Mean ED length of stay (LOS) was 15.4 ± 21.3 h and hospital LOS was 13.1 ± 17.3 days. There were 167 (0.3%) DOA cases.

There were 185 (0.3%) cases with missing information about triage acuity, 138 (0.3%) cases concerning EMS use, 133 (0.2%) cases concerning injury, and 95 (0.2%) cases concerning the transfer variable. Missing data were not designated as a dummy variable. Other baseline data are presented in Table 1.

Of the total number of patients enrolled in this study, 1,975 (3.6%) died. We collected the data from the follow-up date of all enrolled patients after ED discharge or hospital discharge. After that, we could determine the survival status of patients per day. Data of the survival status at 1 day were available in 39,370 (72.4%) patients. Data of survival status at 7 day were available in 35,816 (65.8%) patients.

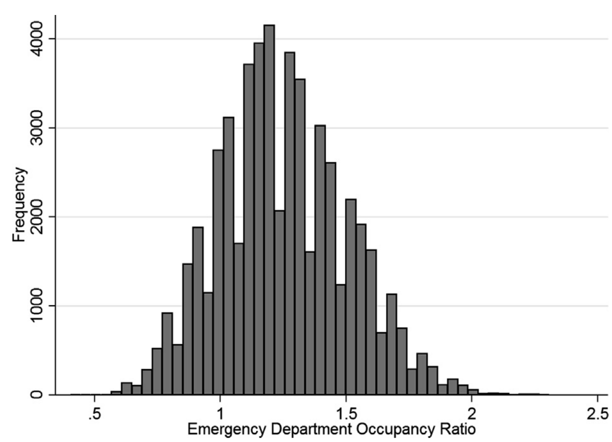

Figure 1. Histogram of the emergency department occupancy ratio distribution.

Table 1. Baseline Characteristics of Enrolled Patients

N	54,410
Age, y, mean (SD)	53.9 (19.3)
Sex (% of male)	30,246 (55.6)
EMS transport, n (%)	10,392 (19.1)
Transferred, n (%)	14,856 (27.3)
Visit during weekend and holiday, n (%)	17,734 (32.6)
Shift, n (%)	
Day (7 am–3 pm)	22,077 (40.6)
Evening (3 pm–11 pm)	21,659 (39.8)
Night (11 pm–7 am)	10,674 (19.6)
Triage acuity, n (%)	
Immediate	2749 (5.1)
Emergent	12,451 (22.9)
Urgent	34,178 (62.8)
Semi-urgent	2804 (5.2)
Non-urgent	2043 (3.8)
Missing	185 (0.3)
Visit cause, n (% of injury)	13,091 (24.1)
Surgical intervention, n (%)	1.938 (3.6)
SBP, mm Hg, mean (SD)	125.8 (28.5)
DBP, mm Hg, mean (SD)	77.3 (16.5)
Pulse rate, bpm, mean (SD)	82.8 (18.5)
Respiratory rate, bpm, mean (SD)	20.0 (3.0)
Body temperature, °C, mean (SD)	36.5 (1.5)
Mental status (%)	
Alert	50,445 (92.7)
Verbal	1536 (2.8)
Pain	1411 (2.6)
Unresponsive	1018 (1.9)
EDOR, mean (SD)	1.25 (0.26)
ED LOS of all patients, h, mean (SD)	15.4 (21.3)
Total hospital LOS of all patients, h, mean (SD)	129.3 (299.1)
Ward admission, n (%)	16,968 (31.2)
ICU admission, n (%)	3441 (6.3)
Hospital LOS among admitted patients, days, mean (SD)	13.1 (17.3)
Overall in-hospital mortality cases, n (%)	1975 (3.6)
1-Day in-hospital mortality cases (39,370 available)	787 (2.0)
2-Day in-hospital mortality cases (38,019 available)	987 (2.6)
3-Day in-hospital mortality cases (37,369 available)	1085 (2.9)
4-Day in-hospital mortality cases (36.896 available)	1170 (3.2)
5-Day in-hospital mortality cases (36,507 available)	1224 (3.4)
6-Day in-hospital mortality cases (36,178 available)	1265 (3.5)
7-Day in-hospital mortality cases (35,816 available)	1296 (3.6)
Dead on arrival	167 (0.3)

DBP = diastolic blood pressure; ED = emergency department; EDOR = emergency department occupancy ratio; EMS = emergency medical service; ICU = intensive care unit; LOS = length of stay; MAP = mean arterial pressure; SBP = systolic blood pressure; SD = standard deviation.

Table 2. Logistic Regression Analysis of Overall Hospital Mortality among All Adult Patients

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
EDOR		
1st quartile	Reference	Reference
2nd quartile	1.14 (1.01–1.30)	1.14 (0.99–1.32)
3rd quartile	1.27 (0.99–1.28)	1.06 (0.91–1.23)
4th quartile	1.20 (1.06–1.37)	1.10 (0.94–1.27)
Age	1.03 (1.03–1.04)	1.02 (1.02–1.03)
Male sex	1.49 (1.35–1.63)	1.51 (1.35–1.68)
EMS transport	2.35 (2.14–2.59)	1.48 (1.28–1.70)
Transferred	1.87 (1.70–2.05)	1.26 (1.11–1.42)
Visit during weekend and holiday	0.82 (0.75–0.91)	1.04 (0.93–1.17)
Shift		
Day	Reference	Reference
Evening	0.93 (0.85–1.03)	0.98 (0.87–1.09)
Night	0.67 (0.59–0.77)	0.79 (0.67–0.93)
Triage acuity		
Immediate	17.17 (11.83–24.91)	1.68 (1.12–2.51)
Emergent	3.42 (2.36–4.94)	1.16 (0.79–1.70)
Urgent	1.48 (1.02–2.13)	1.00 (0.69–1.46)
Semi-urgent	1.02 (0.64–1.64)	0.71 (0.44–1.16)
Non-urgent	Reference	Reference
Visit cause of injury	0.69 (0.62–0.78)	0.75 (0.65–0.87)
Operation	1.94 (1.61–2.33)	0.93 (0.74–1.18)
Mean arterial pressure	0.96 (0.96–0.966)	0.97 (0.97–0.97)
Pulse rate	0.99 (0.99–0.99)	1.01 (1.01–1.01)
Respiratory rate	0.86 (0.86–0.87)	1.02 (1.00–1.03)
Body temperature	0.92 (0.91–0.93)	1.02 (1.01–1.04)
Mental status		
Alert	Reference	Reference
Verbal	4.76 (3.98–5.70)	2.50 (2.04–3.05)
Pain	8.90 (7.65–10.36)	4.31 (3.58–5.19)
Unresponsiveness	39.08 (34.09–44.80)	9.34 (7.31–11.95)
Treatment result		
ICU admission	7.66 (6.83–8.60)	5.56 (4.79–6.47)
Ward admission	1.57 (1.42–1.75)	2.09 (1.83–2.39)
ED discharge	Reference	Reference

CI = confidential interval; ED = emergency department; EDOR = emergency department occupancy ratio; EMS = emergency medical service; ICU = intensive care unit; OR = odd ratio.

Logistic Regression Analysis

Table 2 shows the OR for overall mortality in total adult patients. On univariable logistic regression, the second and fourth quartiles of the EDOR were associated with overall mortality. However, on multivariable logistic regression analysis, the EDOR was not associated with overall mortality. The fourth quartile of ED LOS showed association with overall mortality.

Logistic regression analysis of day by day overall mortality was also performed in the same manner. Table 3 shows the adjusted ORs for 1- to 3-day mortality in total adult patients. In comparison with the lowest (first) quartile, the highest (fourth) quartile of the EDOR was associated with 1-day mortality (adjusted OR = 1.42; 95% CI 1.08–1.88), 2-day mortality (adjusted OR = 1.31; 95% CI 1.04–1.67), and 3-day mortality (adjusted OR = 1.27; 95% CI 1.02–1.58).

Table 4 shows mortality and ORs of the EDOR quartile for each outcome. For the EDOR, the overall mortality increased with increasing quartile group (*p* value for trend = 0.009). Day by day mortality was also

Table 3. Logistic Regression Analysis of Day by Day Mortality among All Adult Patients

	At 1 Day	At 2 Days	At 3 Days
EDOR			
1st quartile	Reference	Reference	Reference
2nd quartile	1.27 (0.97–1.65)	1.20 (0.95–1.51)	1.14 (0.92–1.42)
3rd quartile	1.11 (0.84–1.47)	1.15 (0.91–1.47)	1.13 (0.90–1.41)
4th quartile	1.42 (1.08–1.88)	1.31 (1.04–1.67)	1.27 (1.02–1.58)
Age	1.03 (1.02–1.03)	1.03 (1.02–1.03)	1.03 (1.02–1.03)
Male sex	1.60 (1.30–1.96)	1.66 (1.39–1.97)	1.56 (1.33–1.84)
EMS transport	1.83 (1.40–2.39)	1.78 (1.42–2.24)	1.95 (1.57–2.41)
Transferred	2.89 (2.22–3.77)	2.57 (2.06–3.21)	2.52 (2.05–3.09)
Visit during weekend and holiday	1.04 (0.84–1.28)	1.04 (0.87–1.25)	1.02 (0.86–1.21)
Shift			
Day	Reference	Reference	Reference
Evening	1.02 (0.82–1.28)	1.02 (0.85–1.24)	1.09 (0.92–1.29)
Night	0.94 (0.72–1.24)	0.95 (0.75–1.20)	0.89 (0.71–1.11)
Triage acuity			
Immediate	9.83 (2.36–40.98)	5.45 (1.96–15.13)	3.92 (1.69–9.11)
Emergent	5.85 (1.42–24.14)	3.55 (1.29–9.74)	2.61 (1.14–5.98)
Urgent	2.42 (0.59–10.01)	1.94 (0.71–5.33)	1.55 (0.68–3.54)
Semi-urgent	2.80 (0.60–13.07)	1.74 (0.56–5.45)	1.39 (0.53–3.61)
Non-urgent	Reference	Reference	Reference
Visit cause of injury	1.12 (0.89–1.40)	0.94 (0.77–1.15)	0.96 (0.80–1.17)
Operation	1.98 (0.97–4.03)	1.65 (1.03–2.66)	1.34 (0.90–1.99)
Mean arterial pressure	0.96 (0.95–0.96)	0.96 (0.95–0.96)	0.96 (0.95–0.96)
Pulse rate	1.01 (1.01–1.01)	1.01 (1.01–1.01)	1.01 (1.01–1.01)
Respiratory rate	1.04 (1.02–1.06)	1.04 (1.02–1.06)	1.04 (1.02–1.05)
Body temperature	1.04 (1.02–1.05)	1.03 (1.02–1.05)	1.03 (1.01–1.05)
Mental status			
Alert	Reference	Reference	Reference
Verbal	3.33 (2.34–4.75)	3.02 (2.23–4.07)	2.80 (2.12–3.70)
Pain	4.91 (3.57–6.74)	4.70 (3.59–6.14)	4.09 (3.18–5.25)
Unresponsiveness	7.55 (5.12–11.15)	7.28 (5.21–10.17)	6.70 (4.90–9.17)
Treatment result			
ICU admission	0.11 (0.07–0.16)	0.39 (0.30–0.51)	0.85 (0.68–1.07)
Ward admission	0.03 (0.01–0.71)	0.11 (0.07–0.16)	0.19 (0.14–0.26)
ED discharge	Reference	Reference	Reference
ED length of stay			
1st quartile	Reference	Reference	Reference
2nd quartile	1.05 (0.79–1.40)	1.08 (0.84–1.39)	0.93 (0.73–1.18)
3rd quartile	1.23 (0.98–1.61)	1.22 (0.97–1.56)	1.11 (0.89–1.39)
4th quartile	0.14 (0.09–0.21)	0.52 (0.40–0.69)	0.64 (0.50–0.81)

ED = emergency department; EDOR = emergency department occupancy ratio; EMS = emergency medical service; ICU = intensive care unit.
Data presented as adjusted odds ratio (95% confidential interval).

increased with increasing quartile group, but only 6-day mortality showed statistical significance (p value for trend = 0.048). As previously stated, the EDOR was associated with 1- to 3-day mortality even after controlling confounder. The EDOR was not associated with 4- to 7-day mortality.

Age, sex, EMS transport, transferred case, triage acuity, operations, vital signs, and ED length of stay remained significant for each regression analysis. There was no difference among shifts except in the case of overall mortality regression analysis. Injury patients died less frequently in the overall mortality analysis. Patients who were admitted to the ICU and to a ward died less frequently in the overall mortality analysis. There was no co-linearity between variables.

DISCUSSION

ED crowding has become a problem worldwide and many studies have demonstrated the adverse effects of ED crowding (1). To determine whether ED crowding is associated with poor outcomes, we used mortality, a definite measure of quality of care. The present study demonstrates that the EDOR is associated with 1- to 3-day mortality in adult patients presenting to the ED of the study hospital, even after adjusting for potential confounders. However, the EDOR was not associated with 4- to 7-day mortality or with overall mortality. And the adjusted OR became greater as the number of days became shorter (adjusted OR [AOR] of 1-day in-hospital mortality > AOR of 2-day in-hospital mortality > AOR of 3-day in-hospital

Table 4. Mortality and Odds Ratio of the Emergency Department Occupancy Ratio Quartile for Each Outcome

	1st Quartile	2nd Quartile	3rd Quartile	4th Quartile	*p* for Trend
1-Day mortality (%)	1.27	1.37	1.27	1.50	0.190
Unadjusted OR (CI)	Reference	1.09 (0.89–1.33)	1.00 (0.81–1.23)	1.19 (0.97–1.46)	
Adjusted OR (CI)	Reference	1.27 (0.97–1.65)	1.11 (0.84–1.47)	1.42 (1.08–1.88)	
2-Day mortality (%)	1.56	1.68	1.63	1.86	0.088
Unadjusted OR (CI)	Reference	1.09 (0.90–1.30)	1.05 (0.87–1.27)	1.20 (1.00–1.44)	
Adjusted OR (CI)	Reference	1.20 (0.95–1.51)	1.15 (0.91–1.47)	1.31 (1.04–1.67)	
3-Day mortality (%)	1.74	1.86	1.85	2.08	0.059
Unadjusted OR (CI)	Reference	1.07 (0.89–1.27)	1.06 (0.89–1.27)	1.20 (1.00–1.42)	
Adjusted OR (CI)	Reference	1.14 (0.92–1.42)	1.13 (0.90–1.41)	1.27 (1.02–1.58)	
4-Day mortality (%)	1.95	1.98	2.04	2.24	0.093
Unadjusted OR (CI)	Reference	1.02 (0.86–1.20)	1.05 (0.88–1.24)	1.15 (0.98–1.36)	
Adjusted OR (CI)	Reference	1.05 (0.86–1.29)	1.07 (0.87–1.32)	1.17 (0.95–1.44)	
5-Day mortality (%)	2.07	2.06	2.15	2.38	0.080
Unadjusted OR (CI)	Reference	1.00 (0.85–1.17)	1.04 (0.88–1.23)	1.15 (0.98–1.35)	
Adjusted OR (CI)	Reference	1.01 (0.83–1.24)	1.06 (0.86–1.29)	1.14 (0.95–1.40)	
6-Day mortality (%)	2.13	2.16	2.28	2.47	0.048
Unadjusted OR (CI)	Reference	1.01 (0.86–1.19)	1.07 (0.91–1.26)	1.16 (0.99–1.36)	
Adjusted OR (CI)	Reference	1.03 (0.85–1.25)	1.09 (0.89–1.32)	1.15 (0.95–1.40)	
7-Day mortality (%)	2.22	2.28	2.36	2.55	0.064
Unadjusted OR (CI)	Reference	1.03 (0.88–1.21)	1.07 (0.91–1.25)	1.16 (0.99–1.35)	
Adjusted OR (CI)	Reference	1.05 (0.87–1.27)	1.07 (0.88–1.29)	1.13 (0.93–1.37)	
Overall mortality (%)	3.27	3.72	3.67	3.90	0.009
Unadjusted OR (CI)	Reference	1.14 (1.01–1.30)	1.13 (1.00–1.28)	1.20 (1.06–1.37)	
Adjusted OR (CI)	Reference	1.14 (0.99–1.32)	1.06 (0.91–1.23)	1.10 (0.94–1.27)	

CI = confidence interval; OR = odds ratio.

mortality). This result implies that the effect of ED crowding on mortality might be greatest early on and diminish over time.

Quality of Care in the Throughput Process

The reasons that ED crowding causes poor outcomes are complex. A previous study suggested that crowding led to inferior care in terms of standard performance (starting appropriate treatment within triage, the LWBS rate, and being boarded in the ED) (11). A recent population-based retrospective cohort study using health administrative databases in Canada suggests that poor outcomes during ED crowding might be associated with reluctance to order time-consuming tests or consultations and shortened observation periods, incomplete treatment, or inadequate planning and poor communication of care after discharge (12). More specifically, ED crowding negatively affects time-sensitive treatment. The time from antibiotic ordering to administration for pneumonia patients was prolonged with higher ED volumes (13–15). The time to PCI was prolonged with ED crowding in acute myocardial infarction (AMI) patients requiring PCI and door-to-needle times for patients with suspected AMI increased (16,17). ED crowding also affects the diagnostic process. Computed tomography (CT) is delayed in stroke patients who have symptoms for 3 h at higher levels of ED crowding (18). CT interpretation is also delayed in acute abdominal pain (19). In addition, medication error and lack of monitoring is also substantial at higher levels of ED crowding (20–22).

A delay of diagnosis and treatment, lack of monitoring, and medication error can result in negative outcomes, particularly for critically ill patients. In past decades, the ED had become an important place to provide critical care because of the increasing number of patients, limited ICU bed availability, and increasing levels of patient acuity (23–26). Early stabilization is imperative in critically ill patients; however, ED crowding can negatively affect early stabilization because of the low quality of care mentioned here and, consequently, affect mortality. Our assumption is that ED crowding affected critically ill patients negatively in the present study, however, we could not analyze subgroups in the present study.

EDOR as a Measure of ED Crowding

For decades, the input-throughput-output model was the most widely accepted conceptual framework of ED crowding (4). Many ED crowding measures, based on each step of this model, have been introduced; however, there is no widely accepted one to measure ED crowding. Until now, some studies have shown an association between mortality and ED crowding using boarding time, ED visits per week, occupancy during shifts, overcrowding hazard scale, and waiting times during shift (11,12,27–29). However, none of these measures seem to be suitable for real-time monitoring of ED crowding.

Since McCarthy et al. introduced the EDO rate (EDO ratio in this study) as a simple measure of ED crowding, some studies have been performed using this simple

measure (5). The EDOR is associated with increased time to antibiotic treatment for patients admitted with pneumonia (10). The EDOR predicted leaving without being seen and ambulance diversion hours with moderate accuracy (5). The average daily EDOR discriminates the number of patients who left without being seen (8).

Because of its simplicity, some problems of the EDOR can be raised to measure ED crowding. One major problem is that every additional patient contributes equally to the measure of crowding, thus the EDOR cannot actually reflect disease severity among patients. To overcome this problem, we adjusted the physiologic variables and triage acuity within regression models. After all, the EDOR remained as a predictive factor for early mortality.

In most cases, the number of beds in the ED means the quantity of resources assigned to the ED in the hospital. For example, in the study hospital the number of beds was 42, which means that the study hospital directors consider that it is enough to allocate human and nonhuman resources to the ED for management of up to 42 patients at a given time under a situation of the study hospital. In this context, the EDOR does not only mean the number of beds equipped in the ED, but also represents the resources that the hospital allocated to the ED.

Given the association between the EDOR and increased early in-hospital mortality in the present study, we suggest that the EDOR can be used to monitor patients' risk associated with ED crowding in real time. Clinicians and politicians should implement the policies previously introduced in the other studies to reduce ED crowding when the EDOR is high (30).

Limitations

The results of this study must be interpreted in the context of some limitations. This study represents a retrospective observational study performed in a single center. Although we adjusted for known confounders, we could not completely exclude the residual effect of confounding. As this was an explorative study, multicenter-based larger prospective studies would be necessary to determine the importance of the EDOR in patients presenting to the ED.

Second, our model could not include broad admission/discharge diagnosis categories, although we classified patient-visit causes as injury and noninjury. Time-sensitive medical conditions, such as ST segment elevated myocardial infarction or ischemic cerebral infarction, were more affected by crowding than others, and including these categories may change the risk adjustment.

Third, the EDOR was captured from both adult and pediatric patients, yet the outcome of interest was adult mortality. Because registration to our OCS and triage did not separate adult and pediatric patients, we could not help but calculate the EDOR in this way. Because adult and pediatric care after triage are compartmentalized in the study hospital, it may be negligible how pediatric occupancy affects the care of adult patients.

Fourth, concurrent hospital occupancy was not analyzed in the present study. High occupancy on the ward might cause early mortality after admission and this possibility was not analyzed in the present study.

CONCLUSIONS

In conclusion, even after controlling for potential confounders, the fourth quartile of the EDOR was associated with 1- to 3-day mortality in comparison with the lowest quartile of the EDOR. Because mortality is a marker of good health care quality, the EDOR, a simple to collect and easy to real-time trace, can be used to manage ED crowding for the safety of ED patients. Because the results of the present study are confined to the study hospital, a multicenter-based large cohort study is needed.

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ARTICLE SUMMARY

1. Why is this topic important?

Until now, there was no consensus about emergency department crowding measurement. The emergency department occupancy ratio (EDOR) is easy to collect and usable in real-time situation, however, there is no study that reveals the association between the EDOR and mortality.

2. What does this study attempt to show?

This study attempts to show the association between the EDOR and mortalities that are based on survival data at discharge and at 1–7 days after ED visit.

3. What are the key findings?

Even after controlling for potential confounders, the fourth quartile of the EDOR was associated with 1- to 3-day mortality in comparison with the lowest quartile of the EDOR. The EDOR was not significantly associated with 4- to 7-day mortality and overall mortality at discharge.

4. How is patient care impacted?

Because mortality is a marker of good health care quality, the EDOR, a simple to collect and easy to real-time trace, can be used to manage ED crowding for the safety of ED patients.